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(54) Improvements in or relating to metal spinning

(57) An automatic metal spinning machine includes a forming roller 24, carried on a top slide 34 slidable in an "X" direction on a top slide bed 32 which in turn is slidable in a "Y" direction on a bottom slide bed 30. Movement of the top slide 34 and roller 24 is controlled by a driving cylinder 38 acting on the slide 34 via a holding cylinder unit 44 supplied with gas or liquid under predetermined pressure whereby the roller 24 exerts a corresponding pressure on the workpiece 16 being spun. Switches are operated by the piston in the holding cylinder unit 44 when the piston is extended or retracted beyond respective predetermined positions and the switches operate in a feed-back loop controlling extension of cylinder 38, so as to maintain the piston in an intermediate position maintaining a constant pressure. The machine can thus adapt rapidly to variations in workpieces.

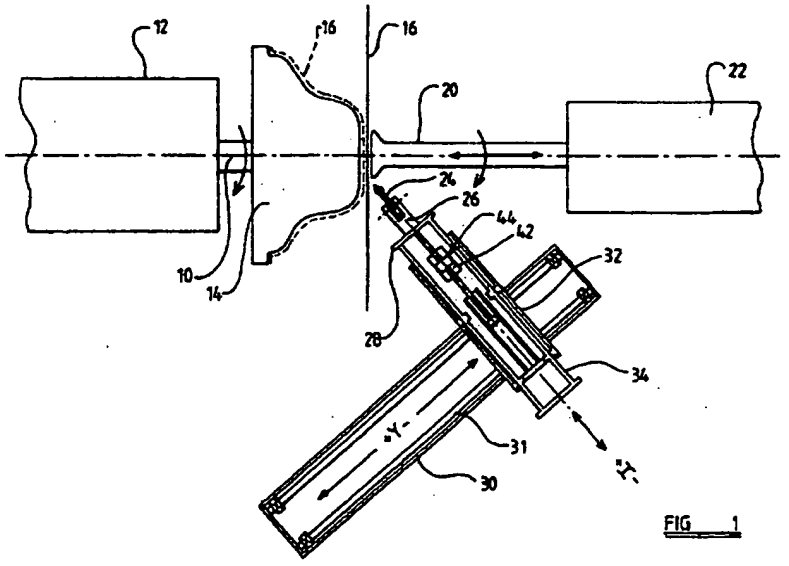

FIG 1

GB 2 302 832 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

DESCRIPTION OF INVENTION

Title: "Improvements in or relating to metal spinning"

THIS INVENTION relates to metal spinning.

Metal spinning is a technique in which a workpiece, in the form of a metal plate, is supported in an apparatus similar to a lathe, in conjunction with a former or spinning chuck, and is rotated in its own plane in the apparatus with the former or spinning chuck, whilst a forming tool is pressed against one surface of the plate and is traversed across the plate from centre to edge and/or *vice versa* over one or more passes. Metal spinning, as a technique for producing metal articles of various kinds in the form of thin shells possessing rotational symmetry about an axis, has largely been superseded, for most applications, by such techniques as press drawing of sheet metal. However, there are applications in which metal spinning, as a technique, is advantageous, for example where production runs are too small to justify the capital cost of metal drawing dies.

Formerly, metal spinning was a skilled operation carried out manually by a skilled workman using a hand tool for forming the workpiece. The skilled spinner was able to tell from the "feel" of the workpiece just how much pressure to apply and how rapidly to force the metal towards the spinning chuck and lack of skill in these respects would lead to spoiled or imperfect products.

Automatic spinning machines are known in which the position of the spinning tool on the workpiece and relative to the spinning chuck or former at any time during the

spinning operation is controlled by computer (CNC) in such a way that the position of the spinning tool at any point in the cycle is determined solely by the time which has elapsed since the beginning of the cycle. The cycle followed by the machine in forming a workpiece is essentially a reproduction, by the machine, of the cycle imposed upon the spinning tool by a skilled operator during spinning of a representative workpiece during a set-up procedure. The cycle of movements during the set-up procedure is recorded in memory in the machine and is reproduced by the machine for subsequent workpieces formed.

Such CNC automatic spinning machines operate satisfactorily with certain metals in certain sheet metal gauges, but operate less satisfactorily with other metals and metal gauges. In particular, such machines operate less satisfactorily with workpieces of relatively thin aluminium sheet. The reason for the less than satisfactory results obtained in these instances is believed to lie in inherent differences in nominally identical workpieces due to such factors as the variable built-in stresses within the sheet metal stock which result in one workpiece behaving slightly differently from another. A skilled spinner can, it seems, compensate for differences between workpieces by subtle variations in technique but conventional CNC automatic spinning machines are unable to make these subtle adjustments, hence the unsatisfactory performance of such machines.

It is one object of the invention to provide an improved automatic spinning machine which is responsive to the behaviour of the workpiece being formed, and which is capable of producing products of more consistent wall thickness and higher quality than hitherto.

The applicants have discovered that surprisingly, when a sheet metal workpiece is properly spun by a skilled spinner, the pressure exerted by the spinning tool on the workpiece actually remains substantially constant, although this fact does not appear to have been fully appreciated in the art.

According to one aspect of the invention there is provided metal spinning apparatus including means for supporting a sheet metal workpiece and for rotating the workpiece, a spinning or forming tool, means for traversing the spinning tool or forming tool between a radially inner position and a radially outer position on the workpiece and means for advancing the forming tool against the workpiece, the last-mentioned means including advancing means for advancing a first member, a piston and cylinder unit interposed between said first member and said spinning or forming tool, means for maintaining in said piston and cylinder unit a fluid pressure biasing said tool towards the workpiece, means for sensing the position of the piston in said piston and cylinder unit relative to the cylinder therein and control means controlled by said sensing means for increasing the rate of advance of said advancing means if said piston and cylinder unit is extended beyond a predetermined extent and for decreasing said rate of advance if said piston and cylinder unit is retracted beyond a predetermined extent.

It is another object of the invention to provide an improved automatic metal spinning apparatus which can be manufactured more cheaply than known automatic metal spinning apparatus.

Thus, in preferred embodiments of the invention said control means comprises a simple feedback loop, and

the control of said means for traversing and means for advancing is otherwise simply controlled by timing means.

It is an object of the invention in another of its aspects to provide an improved method of spinning workpieces, which is capable of providing workpieces of better and more consistent quality than known methods without skilled labour.

According to this aspect of the invention there is provided a method of spinning a metal workpiece rotated in workpiece supporting means comprising traversing a spinning or forming tool over the workpiece in one or more passes, whilst maintaining a substantially uniform pressure of the spinning or forming tool on the workpiece.

An embodiment of the invention is described below by way of example with reference to the accompanying drawings in which:-

FIGURE 1 is a schematic plan view of an automatic spinning machine embodying the invention and

FIGURE 2 is a schematic diagram of a control arrangement of the machine.

Figure 1 shows schematically a spinning machine according to the invention. This comprises, in manner known *per se*, a driven shaft 10 driven in rotation by means (not shown) within a headstock housing 12 for driving the shaft 10 in rotation. At the end of the shaft 10 remote from the housing 12 the shaft terminates in a chuck or former 14. A sheet metal workpiece 16 is gripped between this former 14 and an opposing tail stock or idling shaft 20 rotatably mounted in bearing means in a tailstock

housing 22. The shaft 20, coaxial with shaft 10, can be retracted axially away from the former 14 to release the workpiece 16 when desired, for replacement by a fresh workpiece.

The apparatus includes a spinning tool comprising a roller 24 which is adapted to bear upon the surface of workpiece 16, the roller 24 being supported by a bearing block 26 connected to a slide arrangement.

The slide arrangement comprises a lower slide bed 30 extending at a preset angle to the axis of shaft 10 and which supports an upper slide bed 32 for linear sliding movement on the lower slide bed 30 longitudinally, along the directions indicated by Y in Figure 1. The upper slide bed 32 extends, in the arrangement shown, at right angles to the bed 30 and supports a top slide 34 for linear sliding movement in directions X perpendicular to the directions Y. The arrangement is such that movement of the top slide bed 32 along the bottom slide bed 30 in the direction Y and movements of the top slide arrangement 34 relative to the top slide bed 32 in directions X result in movement of the rotary axis of roller 24 in a predetermined plane which contains the axis of the shaft 10.

As regards the construction of the top slide arrangement 34, in the arrangement shown the roller 24 and roller bearing block 26 are connected to a front plate 28 of the top slide assembly 34. The front plate 28 is mechanically connected to slide shafts which are housed in bearings attached to the top slide bed 34. This top slide bed plate likewise has bearings receiving fixed slide shafts 31 carried by the bottom slide bed. The upper slide bed 32 also has, secured thereto, a driving cylinder 38 of a driving cylinder unit extending axially in the X

direction. The piston rod 40 of the driving cylinder unit extends forwardly from cylinder 38, towards the workpiece, the forward end of piston rod 40 being connected with the cylinder proper, indicated at 42, of a piston and cylinder unit 44 referred to herein, for convenience, as the holding cylinder unit. A piston rod extends forwardly from the cylinder 42 and is secured at its forward end to the front plate 28. The function of the driving cylinder unit is to impart controllable displacement and velocity to the roller 24 and in principle any means of serving this purpose may be used. Whilst, in the embodiment illustrated, a pneumatic driving cylinder unit is used, it will be appreciated that, instead, a hydraulic driving cylinder unit may be used, or an electric motor driving a screw driving a displacement member replacing the piston rod 40 and so on. For this reason the piston rod 40 is also referred to herein as a drive rod.

Associated with the holding cylinder unit 44 are three switches, indicated at SW1, SW2 and SW3 in Figure 2, which respectively sense when the piston in the cylinder 42 has moved forward relative to the cylinder 42 past a predetermined position; when the piston is in a predetermined central position in the cylinder 44 and when the piston has moved rearwardly relative to the cylinder 42 beyond a rearward limiting position. The switches SW1 and SW3 take part in the control of the machine, during spinning, as described below. The switch SW2 is used predominantly in setting up the machine.

In use of the apparatus, an initially flat aluminium plate 16 is clamped centrally between the former 14 and the tailstock 20, the roller 24 being initially retracted away from the metal sheet. The position at this point in the process is substantially that shown in Figure

1. The shaft 10, and hence the plate 16 and countershaft 20, are then rotated whilst the top slide arrangement and with it roller 24 is advanced in the positive X direction, towards the workpiece, to bring the roller 24 to bear on the workpiece and the top slide bed 32 is moved along the bottom slide bed 30 in the positive Y direction for the first pass in the process by which the plate 16 is formed by spinning.

Subject to the constraints described below, the top slide 34 and roller 24 may move either in the positive or negative X direction at different instants during the spinning process according to the demands of the material and the shape to be formed. The movement of the top slide bed 32 on the bottom slide bed is likewise a to-and-fro-movement, so that in a first pass the roller 24 may move from a position close to the centre of the plate 16 to a position close to its periphery as the top slide bed 32 is moved in the positive Y direction on the bottom slide bed 30; in a second pass the roller 24 may be moved from its position close to the periphery of the plate 16 back to a position close to the centre of the workpiece during displacement of the top slide bed 32 in the negative Y direction relative to the bottom slide 30, in a third pass, with the top slide bed 32 again moving in the positive Y direction on the bottom slide bed 30, the roller 24 may again move towards the periphery of the workpiece, and so on. During spinning of a particular product the machine carries out a predetermined number of such passes according to a predetermined pattern of such movements stored in a computer controlling the machine.

Figure 2 shows the top slide arrangement schematically in relation to its control equipment. It will be appreciated that, as described above, the cylinder

42 of the holding cylinder unit is movable in the X directions relative to the top slide bed 32, to which the cylinder 38 of the driving cylinder unit is fixed. The holding cylinder unit follows, overall, the X movements of the roller but, as described below, the system allows for relative movement between roller 24 and the cylinder 42 of the holding cylinder unit, according to the resistance to forming presented by the workpiece 16. Thus, upon encountering higher or lower resistance the holding cylinder unit will extend or retract according to the advancement or retraction of the driving rod of the driving cylinder unit in response to that resistance.

Referring more particularly to Figure 2, the driving cylinder unit and holding cylinder unit are powered by compressed air from a compressed air source indicated schematically at 60. (As noted above the system may be embodied as a hydraulic rather than a pneumatic system. As likewise indicated above, the driving rod 40 may instead be advanced and retracted by any other suitable means, such as a feedscrew driven by an electric or other motor having associated control means, the holding cylinder unit still being operated pneumatically or hydraulically). In the embodiment illustrated, from the source 60, the compressed air is supplied, *via* a proportional control valve 62 to the rear end of the cylinder 42 of the holding cylinder unit 44 and is supplied, *via* a proportional control valve 64 to the rear end of the driving cylinder 38. (Provision is made for moving the piston in the driving cylinder rearwardly at the end of a spinning operation. Such provision is not illustrated in the drawings but may be afforded by making the driving cylinder 38 double-acting. However, no compressed air connection to the front end of the driving cylinder 38 is illustrated because, in the simplest case, any supply of compressed air to the front end of the

double-acting driving cylinder 38 is not involved in the spinning-pressure-regulating control system to be described).

The compressed air supply line from the valve 62 to the holding cylinder 44 is connected with a first pressure transducer 66. Similarly, the compressed air line extending between the proportional control valve 64 and the rear end of the driving cylinder 38 is also connected with a second pressure transducer 68. The pressure transducers 66, 68, provide analog signals, proportional to the pressures sensed by them in the respective compressed air supply lines, to respective ports of an analog to digital converter 70 which supplies corresponding information, in digital form, to a computer 72 controlling the operation of the spinning machine. Conversely, the proportional control valves 62 and 64 are controlled by analog signals provided by a digital to analog converter 74 receiving respective digital signals from the computer 72. The proportional control valves 62, 64, function to maintain the pressure in the downstream compressed air lines connected thereto at respective values proportional to the magnitude of the analog signals to the respective proportional control valves from the digital to analog converter 74.

The switches SW1 and SW3 associated with the holding cylinder are also connected with the computer 72 as indicated. It will be appreciated that various other limit switches, position detectors, etc. are associated with various parts of the apparatus, in manner known *per se* and provide respective signals to the computer 72 allowing the latter to determine, for example, when the top slide and top slide bed have reached the limits of their movement and so on. As in known computer-controlled automatic spinning machines, apparatus is also provided for trimming scrap

border parts from the spun products, after completion of spinning of a workpiece, for removing the spun products from the former 14 and so on.

The computer 72 is arranged to carry out certain pre-programmed movements, including, after mounting of the workpiece blank, the bringing of the parts of the apparatus to the position shown in Figure 1 and the advance of the roller 24 to engage the workpiece adjacent the centre of the latter. The program stored in the computer 72 is also arranged to cause the top slide bed 32 to be moved back and forth along the bottom slide bed 30 in a predetermined number of passes, between limiting positions predetermined for each pass (and not necessarily the same for each pass - given the changing shape of the workpiece during the spinning operation). However, the computer does not directly control the position of the roller 24 in the X direction during the spinning operation but does control the pressures applied to the holding cylinder unit and driving cylinder unit as discussed below. In principle, throughout the spinning operation, the holding cylinder 44 is supplied with air at a constant predetermined pressure tending to urge the piston and piston rod of the holding cylinder unit 44 forwards, (i.e. towards the workpiece) relative to the cylinder proper. This pressure is selected according to the composition, thickness, etc. of the material of the blank 16 to be spun. The absolute value of the pressure depends, of course, additionally on other factors such as the cross sectional area of the piston in the holding cylinder unit. The pressure of the compressed air applied to the driving cylinder 38 from the proportional control valve 64 during the spinning operation may be substantially constant or may be arranged to vary with time in a predetermined manner in accordance with the program stored in the computer 72, for example to

compensate for throttling of inflow through the compressed air line between the valve 64 and the cylinder 38 during periods in the spinning process where the roller 24 is moving relatively rapidly in the X direction.

The manner in which the pressure of the compressed air supplied to the cylinder 38 is controlled is such that, in principle, the position of the piston in the holder cylinder unit 44 is maintained substantially between limiting positions defined by the switches SW1 and SW3.

In the following, it is assumed that the constant pressure selected for the holding cylinder in the particular apparatus described, for a particular workpiece in a particular material, e.g. aluminium sheet, is 3.2 bar.

The basic operation of the apparatus during spinning is as follows:

(i) Suppose that at some point, the blank exhibits a higher resistance to the forming than that represented by the nominal pressure of 3.2 bar. This will result in the compression of the holding cylinder unit in compound with the extension of the driving cylinder unit (thus cushioning the applied force). That is to say, the piston in holding cylinder unit 44 will move rearwards relative to its cylinder 42 (although the piston may be moving forwards or rearwards relative to the upper slide bed 32). The holding cylinder unit will continue to compress until limit switch SW3 (Figure 2) is operated. The computer 72 on detecting the operation of switch SW3 alters the value of the controlling signal applied to valve 64 so that the pressure of the air supply to the driving cylinder

is decreased enabling the cylinder 42 of the holding cylinder unit to move rearwardly relative to its piston and thus allowing the piston in the holding cylinder to return to its position at which limit switch SW1 is operated. On detecting operation of switch SW1, the computer restores the programmed value to the signal to valve 64 and thus restores "normal" pressure to the driving cylinder unit.

(ii) Suppose that at some other point, the blank exhibits a lower resistance to forming than that represented by the nominal pressure of 3.2 bar. This will result in the extension of the holding cylinder unit in compound with the compression of the driving cylinder unit. That is to say, the piston in holding cylinder unit 44 will move forwards relative to its cylinder 42 (although, again, the piston may be moving forwards or rearwards relative to the upper slide bed). The holding cylinder unit will continue to extend until limit switch SW1 (Figure 2) is operated. The computer 72 on detecting the operation of switch SW1 alters the value of the controlling signal applied to valve 64 so that the pressure of the air supply to the driving cylinder is increased enabling the driving cylinder unit to move the cylinder 42 of the holding cylinder unit 44 forwards relative to its piston and thus allowing the piston in the holding cylinder 42 to return towards its position at which limit switch SW3 is operated. On detecting operation of switch SW3, the computer again restores the programmed value to the signal to valve 64 and thus restores "normal" pressure to the driving cylinder unit.

It should be noted that the control mechanism for the X axis travel of the top slide (see Figure 1) is *via* limit-of-travel sensing of the holding cylinder unit 44 and adjusting of the driving cylinder pressure. It is not via X axis co-ordinate drive.

Once the material has been formed down onto the spinning chuck, the system will signal the need for a finishing stroke. For the finishing stroke, the nominal pressure applied to the holding cylinder unit is dropped slightly, for example, in the particular system under consideration, from 3.2 bars to 2.7 bars. This data point is determined by the operator who produces the first component and is retained for the production of succeeding items.

It is contemplated that, by providing indicators, such as lamps, operable directly or indirectly by the switches SW1 to SW3, and more particularly by switch SW2 and using an appropriate setting program in the computer 72, it will be possible for an unskilled person to set the spinning machine initially, relying upon such indicators or lamps to provide an indication as to when the piston in the holding cylinder unit 44 is in its desired central position, the machine setter manipulating manual controls to maintain this condition, the position of these controls being appropriately detected by the computer during such setting operation, whilst spinning a representative workpiece. Thus, the need for a skilled operative to set the machine initially may be eliminated.

As noted above, the driving cylinder unit may be replaced by some other driving means, such as a feedscrew driven by an electric motor. In such an arrangement, the effect of operation of switches SW1 and SW3 or their

equivalents may be to increase or decrease respectively the "forward" speed of the motor or to decrease or increase respectively the "rearward" speed of the motor, or to change over the motor from "forward" to "reverse" or *vice versa*, in such a way as to maintain, as in the embodiment described with reference to the drawings, the piston in the holding cylinder unit between the limits defined by switches SW1 and SW3.

Whatever the nature of the driving means represented by the driving cylinder unit or by the motor-driven feedscrew, in the alternative, a measure of proportional control may be afforded by providing one or more further pairs of position detector switches at different distances from the mean central position of the holding piston, with the correction applied upon operation of such a switch increasing with distance of the switch operated from said central position.

In a variant, the position of the cylinder 42 of the holding cylinder 42 may be controlled numerically in exactly the same way as is the forming roller 24 in conventional CNC automatic spinning machines, but with the computer being programmed to respond to an overshoot or undershoot detected by the holding cylinder unit 44 by making appropriate adjustment to the nominal required position of the cylinder 42 in the X direction.

The invention makes it possible, however, to construct an automatic spinning machine particularly inexpensively, by dispensing altogether with numerical control of the position of either of the slides 32 and 34 by the computer 72. Thus in a variant utilising this feature, the control, by the computer, of the position of the top slide bed 32 on the bottom slide bed 10 is limited

to reversing the direction of movement of the slide bed 32 along the bottom slide bed 10 at the end of each pass (or at the end of each pass and at the end of the return movement following each pass in a case where working passes are made only unidirectionally, e.g. from the middle of the workpiece outwardly), in response, for example, to the operation of limit switches at the limits, (determined in the simplest case by manual adjustment) of such movement, whilst the computer 72, (or equivalent control means) controls the driving cylinder 38 (or equivalent driving means) simply in a time dependent manner, by reference to total time elapsed from start of the spinning operation or from start of the respective pass. Timing, in this event, may be carried out utilising the clock pulses provided, in any case, for the operation of the computer where this is a digital electronic computer. Thus, for example, the computer may control forward motion of the slide 34 by alternately opening and closing a solenoid operated valve supplying hydraulic fluid or compressed air to the cylinder 38 or by opening and closing a relay (or equivalent electronic device), supplying electrical current to an electric motor serving the function of the cylinder 38 where such a motor is used for advancing the slide 34, in a sequence, stored during the setting of the machine, with a simple control loop incorporating the switches SW1 and SW3 being arranged to override such computer control of the valve controlling cylinder 38 or the relay or other circuit controlling the corresponding motor, when the piston in unit 44 has passed a respective position determined by switch SW1 or SW3, in such a way as to tend to return such piston to a position between such positions. It will be clear that even where it is necessary to provide for retraction of the piston rod 40 or equivalent during such pass, this need involve no more additional complication than the provision of an additional solenoid-controlled

changeover valve or equivalent current switching circuitry controlled by the computer. The elimination of the need for complex accurate electronic position sensors for the slide bed 32 and slide 34, and the storage of corresponding sets of values of forming roller coordinates, significantly reduces the complexity and cost of the apparatus as compared with known automatic metal-spinning machines.

The effect of the apparatus embodying the invention and of the spinning method using such apparatus, is to maintain a constant control upon the deformation to which the workpiece is subjected, thus maintaining substantially uniform material thickness in the finished product without marked spinning lines, so that a high quality product is obtained, even when spinning relatively soft materials such as aluminium sheet.

Furthermore, this effect can be obtained without the need for skilled operatives either to supervise the normal operation of the machine or to set up the machine in preparation for a production run.

CLAIMS

1. Metal spinning apparatus including means for supporting a sheet metal workpiece and for rotating the workpiece, a spinning or forming tool, means for traversing the spinning or forming tool between a radially inner position and a radially outer position on the workpiece and means for advancing the forming tool against the workpiece, the last-mentioned means including advancing means for advancing a first member, a piston and cylinder unit interposed between said first member and said spinning or forming tool, means for maintaining in said piston and cylinder unit a fluid pressure biasing said tool towards the workpiece, means for sensing the position of the piston in said piston and cylinder unit relative to the cylinder therein and control means controlled by said sensing means for increasing the rate of advance of said advancing means if said piston and cylinder unit is extended beyond a predetermined extent and for decreasing said rate of advance if said piston and cylinder unit is retracted beyond a predetermined extent.

2. Apparatus according to claim 1 wherein said advancing means comprises a further piston and cylinder unit supplied with pressurised fluid *via* a throttling restriction and wherein said control means is arranged to increase or decrease the pressure, upstream of said restriction, of the fluid supplied to said further piston and cylinder unit in order to increase or decrease said rate of advance.

3. A method according to claim 2 wherein said advancing means comprises an electric motor and wherein said control means is arranged to increase or decrease the

spread of said electric motor in order to increase or decrease said rate of advance.

4. A method of spinning a metal workpiece rotated in workpiece supporting means comprising traversing a spinning or forming tool over the workpiece in one or more passes, whilst automatically maintaining a substantially uniform pressure of the spinning or forming tool on the workpiece.

5. Metal spinning apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

6. A method of spinning a metal workpiece, substantially as hereinbefore described with reference to the accompanying drawings.

7. Any novel feature or combination of features described herein.

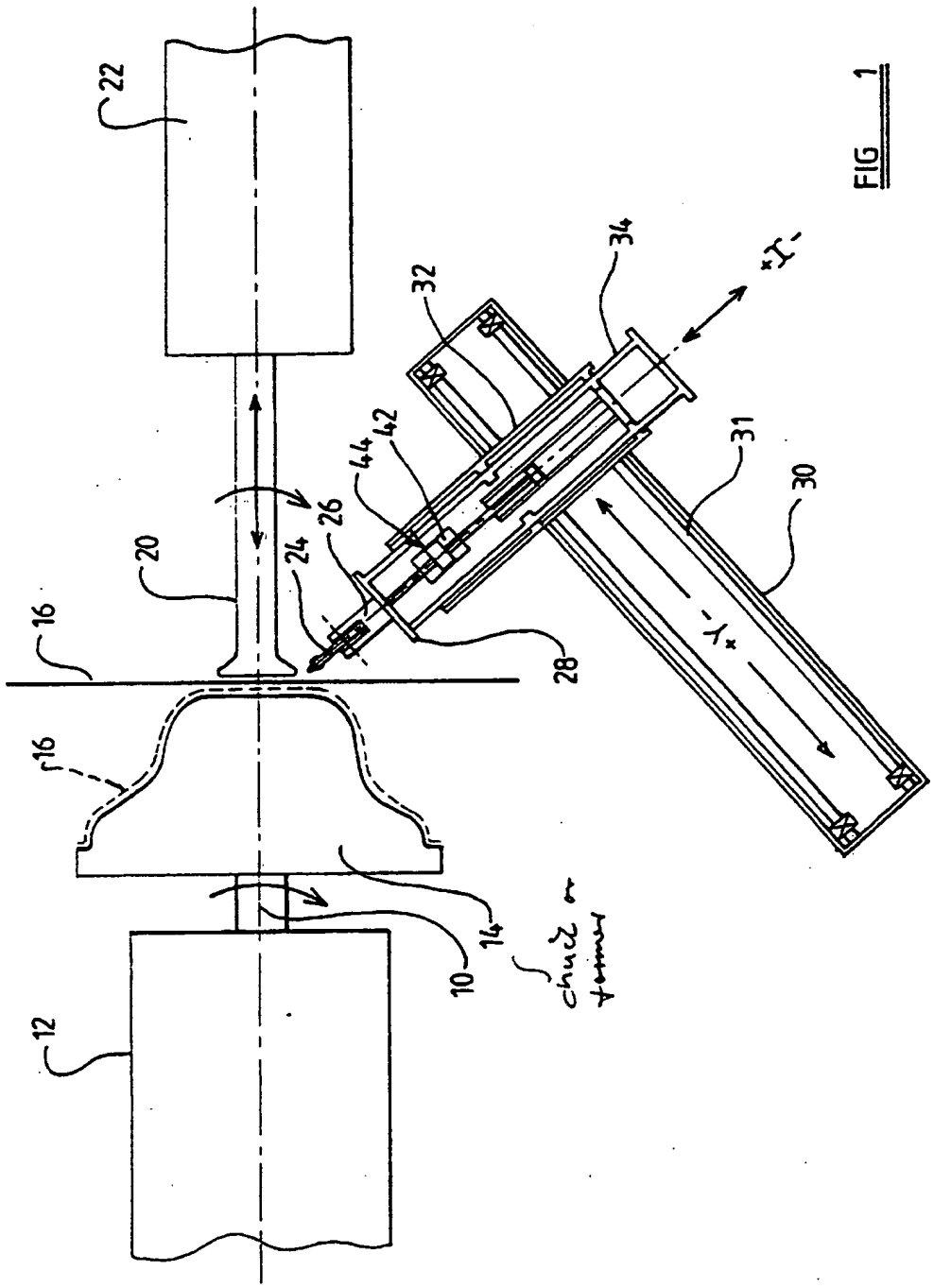

FIG 1

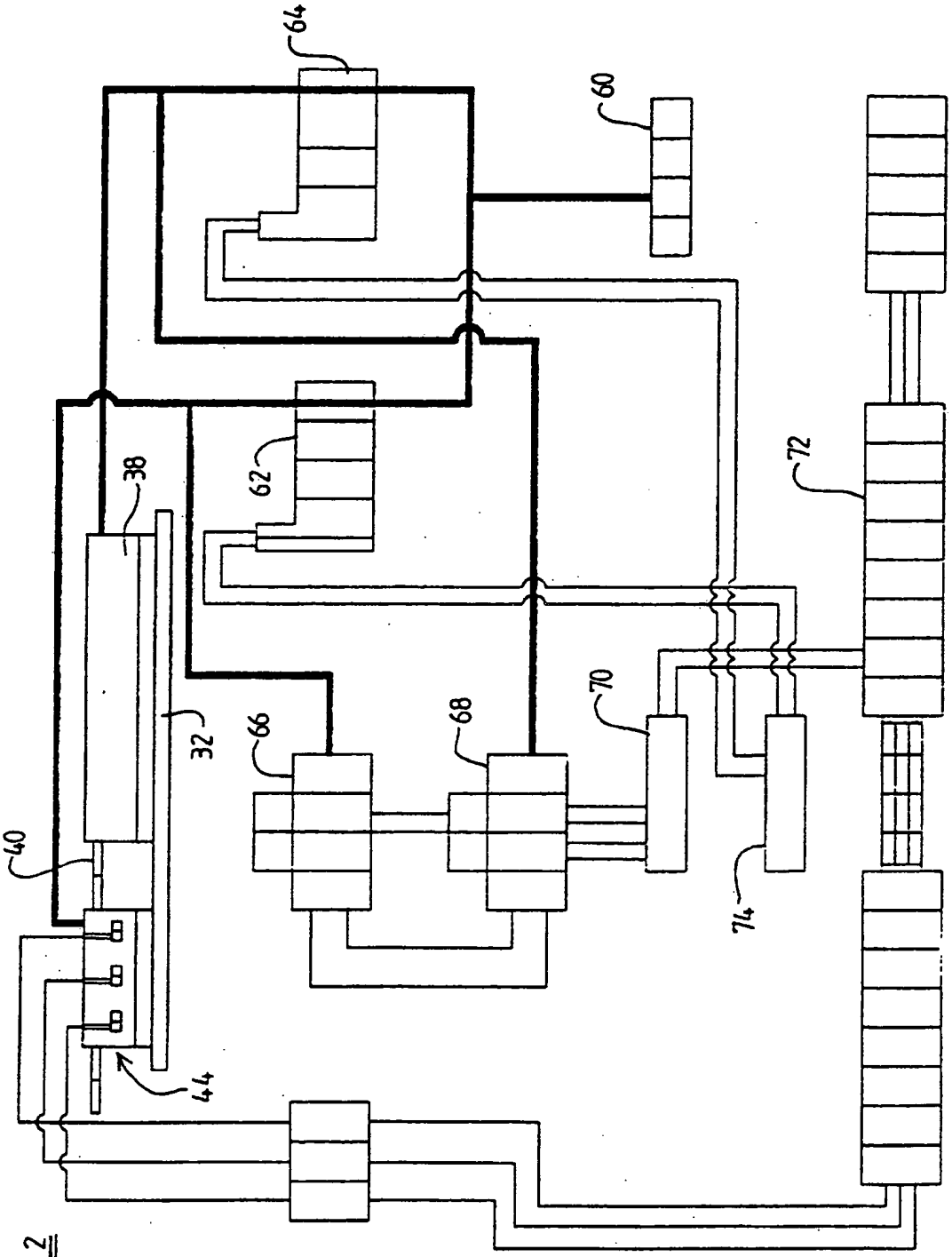

FIG 2